PLANETARY SCIENCE

A cloudy view of exoplanets

The lack of absorption features in the transmission spectrum of exoplanet GJ 1214b rules out a hydrogen-rich atmosphere for the planet. It is consistent with an atmosphere rich in water vapour or abundant in clouds. **SEE LETTER P.669**

DRAKE DEMING

Sometimes the most telling evidence comes not from what is observed but from what is not observed. On page 669 of this issue, Bean and colleagues[1] report results of the latter type for the transiting 'super-Earth' exoplanet GJ 1214b.

This nearby world[2] (it is only about 13 parsecs away from Earth) belongs to the special category of transiting planets. When a planet transits — passes in front of its star as seen from the vantage point of Earth — we can measure its radius from the amount of stellar light that it blocks. By adding precision spectroscopic data, we can also determine its mass from the Doppler 'wobble' that it induces in the parent star's motion. Knowing the mass and radius of an exoplanet is a major step towards characterizing its nature. The mass and radius of GJ 1214b imply that it almost certainly has a massive atmosphere[3].

In their study, Bean *et al.*[1] have pushed the methodology even farther than measuring the mass and radius of GJ 1214b. Their measurements offer the first direct probe of the atmosphere of an extrasolar super-Earth. Super-Earths are planets two to ten times more massive than Earth, and GJ 1214b weighs in at 6.5 Earth masses. Specifically, the authors measured the amplitude of the transit — the amount of starlight that the planet blocks — as a function of wavelength. Molecules such as water vapour in the planet's atmosphere can absorb starlight during the transit, and can do so more strongly at some wavelengths than others, making the amplitude of the transit wavelength-dependent. The pattern of absorption potentially allows specific molecules to be identified.

Using data of exquisite sensitivity, Bean *et al.* show that the transmission spectrum of GJ 1214b is a smooth function of wavelength, with no bumps or wiggles that can be attributed to absorption by atmospheric molecules. It is this absence of specific spectral features that makes the results so intriguing. The simplest molecule, molecular hydrogen, is the easiest to measure, albeit indirectly. Molecular hydrogen produces no absorption features of its own at readily measured wavelengths, but its low molecular mass allows the putative atmosphere to extend to high altitudes. This spreads all of the constituents of the atmosphere over a greater height range, and allows transmitted starlight to interact with many absorbing atoms and molecules (Fig. 1a). Transmission spectra of gas-giant exoplanets[4,5] show detectable spectral features largely for this reason. One signature of a hydrogen-rich atmosphere surrounding a transiting super-Earth will therefore be the ease with which the absorption features are detected.

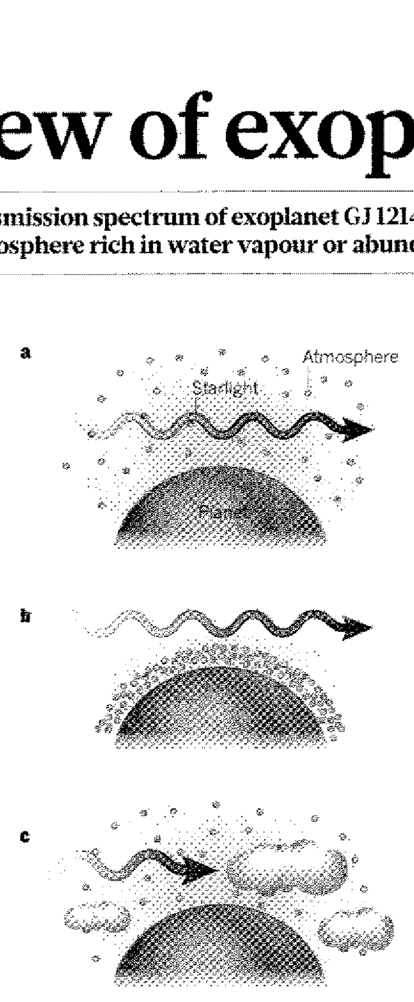

Figure 1 | Possible exoplanet atmospheres. **a**, Hydrogen-rich atmospheres are extended in height, allowing starlight to interact with many absorbing molecules, and producing absorption signatures in the planet's transmission spectrum during transit. **b**, Hydrogen-poor atmospheres have high average molecular mass, and are concentrated at low levels, where most starlight misses the potentially absorbing molecules. **c**, Clouds in the atmospheres of transiting planets can block starlight, so that no — or very weak — absorption features are seen in the transmission spectrum. Bean *et al.*[1] find that the transmission spectrum of exoplanet GJ 1214b rules out a hydrogen-rich atmosphere and is consistent with either a hydrogen-poor atmosphere rich in water vapour or an atmosphere abundant in clouds and haze.

Bean and colleagues' high-precision spectral data[1] rule out a hydrogen-rich atmosphere for GJ 1214b — a significant advance in the field of exoplanetary atmospheric science.

An irony of transit spectroscopy is that atmospheres rich in strongly absorbing complex molecules but poor in weakly absorbing hydrogen will not necessarily lead to a strong absorption signal. Paradoxically, they will tend to produce an absence of spectral absorption features. Hydrogen-poor atmospheres, having greater average molecular masses than hydrogen-rich atmospheres, are pulled by a planet's gravity to lower altitudes, where they intercept relatively few photons from the parent star (Fig. 1b). These low-lying atmospheres, even if they are rich in complex molecules, produce very weak absorption features[6].

One possible interpretation of Bean and colleagues' results[1] showing a lack of absorption features is that this extrasolar super-Earth has an atmosphere rich in molecules heavier than hydrogen. Among molecules heavier than molecular hydrogen, the most cosmically abundant possibility is water. Hence, one particularly intriguing explanation for the authors' results[1] is that the planet is surrounded by an atmosphere rich in water vapour. However, another — and at the moment equally valid — interpretation of their data puts clouds in view for exoplanet transit spectroscopy, both literally and figuratively.

Bean and colleagues' observations are consistent with abundant clouds and haze in the atmosphere of GJ 1214b. Clouds in the atmospheres of giant exoplanets were inferred from the first detection of an exoplanet atmosphere[4], and other results for giant exoplanets have conclusively demonstrated the existence of hazy atmospheres[7]. Clouds and haze intercept and block starlight as it passes through the atmospheres of transiting planets (Fig. 1c), weakening or totally obscuring absorption features. In addition to real clouds, figurative clouds have recently gathered over exoplanet transit spectroscopy: detections of molecular absorptions in data from the Hubble Space Telescope for several giant exoplanets have recently been challenged, and attributed to uncorrectable instrumental effects[8].

Fortunately, both the literal and figurative clouds should clear for transit spectroscopy

of exoplanets. Spectroscopy of GJ 1214b in the near infrared has already been scheduled for Hubble's Wide Field Camera 3 (WFC3). WFC3 observations will probe a longer wavelength than was available to Bean *et al.*, and hazy atmospheres can often be clearer at longer wavelengths. As for giant planets, a new and extensive Hubble programme using WFC3 should clarify many questions concerning their molecular absorptions.

On a longer timescale, astronomers await the advent of the James Webb Space Telescope, which will not only provide excellent sensitivity, but also operate at long infrared wavelengths. At sufficiently long infrared wavelengths, haze and clouds tend to become transparent. Moreover, many molecules have their strongest absorption bands in the long-wavelength infrared region. Sufficiently strong bands can imprint detectable signals on the small portion of the transmitted light that misses the clouds. The James Webb Space Telescope should blow away any remaining clouds surrounding exoplanet spectroscopy, and give us the clearest view yet. ■

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CANCER

Chemotherapy counteracted

Resistance of tumour cells to chemotherapy can severely affect the efficacy of this anti-cancer treatment. The non-tumour cells embedded in the tumour may aid the emergence of such resistance.

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Most cancer-related deaths are due to drug resistance and/or metastatic spread of tumour cells. These two properties of cancer cells have often been viewed — and studied — as separate processes. However, increasingly, this is changing. For instance, cancer stem cells have been shown[1] not only to be resistant to diverse anti-cancer agents, but also to act as the seeds for germinating metastases. In a paper in *Cell*, Gilbert and Hemann[2] describe another particularly interesting example of this deadly relationship. They demonstrate that cancer therapy can acutely alter a tumour's surrounding tissue and organ environment to promote cancer-cell survival, and so to facilitate metastasis and drug resistance. These observations are potentially relevant to enhancing the efficacy of chemotherapy.

Gilbert and Hemann study a mouse model of Burkitt's lymphoma, a cancer of the lymphatic system. They treat the mice with doxorubicin — a DNA-damaging chemotherapeutic agent that is often used to treat human cancers, including lymphomas and breast carcinoma. They note that, as is often the case, tumour cells in most organs respond to this drug, but some cells survive and are eventually detectable, mainly in the thymus gland (Fig. 1). The authors ask why.

They find that doxorubicin induces changes in the expression of several genes in the thymus. Among the genes affected, two seem to be possible culprits in chemoresistance: the gene encoding the inflammatory cytokine IL-6 and that encoding a protein called Timp-1. On more detailed studies of IL-6, Gilbert and Hemann find that the source of this protein is thymic blood vessels. This observation adds to those of previous studies[3], which also suggested that endothelial cells (which line blood vessels) contribute to tumour growth by secreting cytokines — or, as they were more aptly called, angiocrines.

A stress-response signalling pathway involving the enzyme p38 MAPK mediates acute IL-6 release by endothelial cells. Gilbert and Hemann find that IL-6 subsequently acts in a paracrine manner to promote the survival of a small number of doxorubicin-treated tumour cells that lurk in the thymus and can eventually cause extensive metastases *[OK?]*. IL-6 achieves this by inducing the expression of Bcl-X_L — a protein that inhibits programmed cell death. These results add a fascinating chapter to emerging research on the nature of acute, reactive cytokine responses in host tissues that are induced by cytotoxic anti-cancer therapies and may subsequently act to blunt the efficacy of the therapy[4].

Tumour-cell-associated IL-6 secretion has been linked[5] to chemoresistance in several tumour types, and even the role of tumour-associated endothelial cells in mediating chemoresistance is not completely unexpected. The tumour vasculature provides cancer cells with oxygen and nutrients, is a rich source of growth and survival factors, and regulates the influx of bone-marrow-derived cells with tumour-promoting activities[3]. Furthermore, the vascular bed is a fertile ground for cancer stem cells, which are particularly chemoresistant[1,6].

By showing that endothelial cells mediate

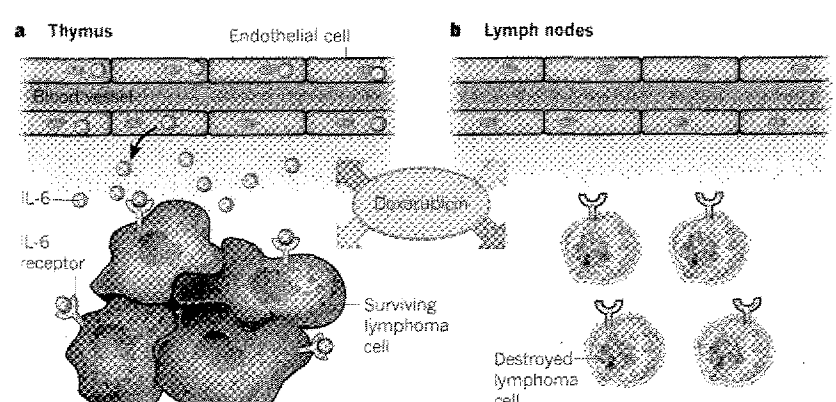

Figure 1 | Endothelial stress response and chemoresistance. a, Gilbert and Hemann[2] find that the chemotherapeutic drug doxorubicin leads to an acute stress response in the tumour vasculature of the thymus that involves the secretion of IL-6 and other cytokines. IL-6 then acts in a paracrine fashion to promote the survival of lymphoma cells expressing the IL-6 receptor. **b,** In the absence of such an endothelial-cell stress response in lymph nodes, doxorubicin can destroy lymphoma cells.